Phys 131 2016

Lecture 15

Tues: Ch 6 Conc Q 10, 16

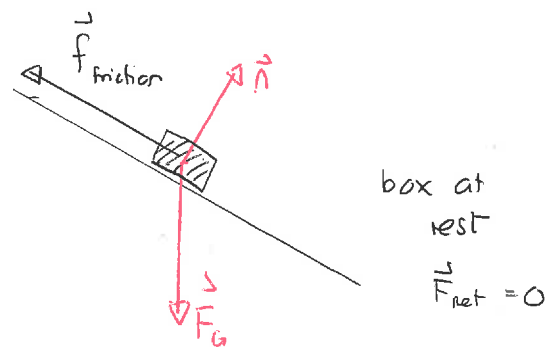
Ch6 Prob 24, 26, 30, 44

Weds: Lecture

Friction

Objects in contact with each other exert various types of contact forces. One of these, a normal force, is always present and is perpendicular to the surfaces. But in many cases there is clearly another force present.

Considering a block at rest on a slope, one can see that the normal and gravitational forces alone cannot add to give a zero net force. There must be another force between the surfaces. The same is true if the object were sliding down the surface at constant speed. These other forces



1) result from the interaction between the atomic constituents of the surfaces

2) are parallel to the surface and oppose the motion or the motion that would arise in their absence.

These are called friction forces and we consider two types:

1) <u>static friction</u> ~ occurs when object is at rest relative to surface $\vec{f}_s$

2) <u>kinetic friction</u> ~ occurs when object moves " " " $\vec{f}_k$

Demo: PhET friction – move surfaces back + forth

Static Friction

Static friction forces have the following properties:

1) The direction of static friction is opposite to the direction in which the object would move in its absence.

2) the magnitude of static friction depends on the other forces present but cannot exceed a maximum

$$f_{s\,max} = \mu_s n$$

where n is the normal force

μ_s " " coefficient of static friction

Thus

$$f_s \leq \mu_s n$$

The coefficient of static friction depends on the materials from which the two surfaces are made. (Table 6.1)

Note: 1) static friction does not depend on contact area.

2) the coefficient of static friction does not equal the friction force. It does help to determine the friction force.

Quiz 1

Kinetic friction

For kinetic friction

1) The direction of the force opposes the motion.

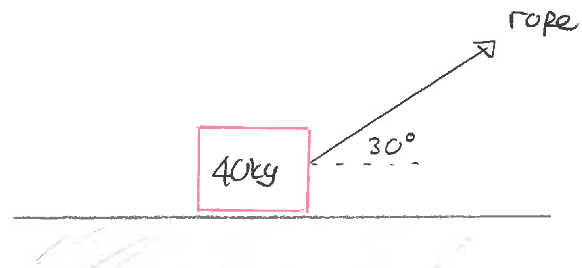
2) the force always has magnitude

$$f_s = \mu_s n$$

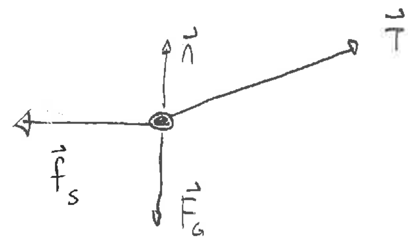
where n = normal force and μ_s = coefficient of static friction

Warm Up!

Example: A 40kg rubber block is at rest on a horizontal surface. A rope pulls on the block as illustrated. If the coefficient of static friction between the surfaces is 0.90 determine the minimum tension needed to move the block horizontally



Answer: (1) FBD



(2) Newton's 2^{nd} Law

$$\sum F_x = ma_x$$

← Says: " Add all horizontal components of forces and set equal to ma_x "

$$\sum F_y = ma_y$$

Now as tension increases, the static friction force increases. But it can only increase up to a maximum. The tension at this point is the minimum needed for the object to move - any larger tension would accelerate the block. We consider this "tipping point"

Here $\vec{a} = 0$ and $f_s = \mu_s n$

Thus
$$\sum F_x = 0$$
$$\sum F_y = 0$$

(3) magnitudes: $F_G = mg$

$$f_s = \mu_s n$$

④ All components of all forces:

$F_{gx} = 0$

$F_{gy} = -mg$

$n_x = 0$

$n_y = n$

$T_x = T\cos 30^\circ$

$T_y = T\sin 30^\circ$

$f_{sx} = -\mu_s n$

$f_{sy} = 0$

	x	y
$\vec{F}_G$	0	$-mg$
$\vec{n}$	0	n
$\vec{T}$	$T\cos 30^\circ$	$T\sin 30^\circ$
$\vec{f}_s$	$-\mu_s n$	0

Note: Although we could substitute numbers there are still two unknowns: T, n

Now Newton's 2nd law gives:

$$\sum F_x = 0 \Rightarrow T\cos 30^\circ - \mu_s n = 0 \quad -(1)$$

$$\sum F_y = 0 \Rightarrow -mg + n + T\sin 30^\circ = 0 \quad -(2)$$

We want T and not n so eliminate n using (2):

$$n = mg - T\sin 30^\circ$$

Thus $\quad T\cos 30^\circ - \mu_s n = 0$

$$\Rightarrow T\cos 30^\circ - \mu_s (mg - T\sin 30^\circ) = 0$$

$$\Rightarrow T\cos 30^\circ - \mu_s mg + \mu_s T\sin 30^\circ = 0$$

$$\Rightarrow T(\cos 30^\circ + \mu_s \sin 30^\circ) - \mu_s mg = 0$$

$$\Rightarrow T(\cos 30^\circ + \mu_s \sin 30^\circ) = \mu_s mg$$

Thus:

$$T = \frac{\mu_s m g}{\cos 30^\circ + \mu_s \sin 30^\circ}$$

$$= \frac{0.90 \times 40\,kg \times 9.8\,m/s^2}{\cos 30^\circ + 0.90 \sin 30^\circ}$$

$$= 270\,N$$